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Neutrosophic fuzzy decision-making framework for site selection

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Abstract

These days, the area of interest based on canteen location selection in the university campus is a prominent topic. This research work directly affects students' convenience, accessibility and the total campus experience. An ideal canteen site not only provides good food to the students and staff but also takes care of their health by providing a healthy environment. In this paper, we choose various criteria and sub-criteria to calculate the best site for a canteen in the university campus. Location, space and layout, infrastructure and Utilities, safety and compliance and environmental factors as criteria with their corresponding sub-criteria are chosen for this work. Here, the data sets used are provided by decision makers in linguistic words and then converted into crisp numbers. The criteria and sub-criteria weights are considered by a popular multi criteria decision-making (MCDM) method named Criteria Importance Through Intercriteria Correlation, i.e., CRITIC method. Therefore, the ideal location for the canteen in the university campus was determined by applying the complex proportional assessment method (COPRAS), which is basically a ranking method of MCDM. And finally, sensitivity analysis was conducted to make sure the outcomes were flexible and stable.

Keywords: Canteen site selection; Educational institute; Triangular neutrosophic number; CRITIC; COPRAS.

1. Introduction

The site selection of the canteen at a university campus is a monumental decision that affects the meal experience of staff and students and mainly the general quality of food. To cater to fulfil people's services, the site must be perfectly situated close to needy places such as academic buildings, libraries, hostels and recreational spaces. It is essential to take into account cooking facilities, enough space for seating and future improvement. Water, power and waste management are everyday essentials that need to be available at the chosen location. Environmental impact and quality of health standards are key factors. An ideal chosen location improves campus life and contributes to the university's effectiveness.

1.1 Necessity of Canteen in educational institute

A canteen on a university campus is required for distributing students and staff to affordable meals that support general well-being, happiness and productivity. An ideal location helps the students to stay focused on their studies. On the other hand, to enhance social communication, a well-organised cafeteria boosts the sense of community on a university campus. It also saves valuable time by avoiding the desire to leave the university premises for food. In addition, it supports flourishing academic performance by providing balanced eating habits, which also serves as a perfect learning environment for the hospitality of the students.

1.2 MCDM methods and applications

In the vast field of operations research, Multi-Criteria Decision Making (MCDM) explores various decision-making problems, including many factors. It has different procedures for finding the criteria weight and computing with different alternatives for making the best optimal selection. There are some well-known MCDM processes utilised for solving real-life decision making problems, they are Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Rahim et al. 2018), VIekriterijumsko KOmpromisno Rangiranje (VIKOR) (Adhikari et al., 2024), Elimination and Choice Translating Reality (ELECTRE) (Vahdani et al., 2013), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) (Uzun et al., 2021), Multi-Objective Optimization based on Ratio Analysis plus Full Multiplicative form (MULTIMOORA) (Brauers and Zavadskas, 2010), Criteria Importance Through Intercriteria Correlation (CRITIC) (Diakoulaki et al., 1995), Complex Proportional Assessment (COPRAS) (Patil et al., 2022), etc.

The above explained decision making processes help to make the perfect and wise decision in difficult situations where it is important to make proper choices between criteria and the preferences of alternatives, as well as improve the procedure's versatility. Generally, all MCDM methods have the benefit of considering inconsistent and conflicting effects of the right decisions.

1.3 Motivation of this study

The motivation for the paper is raised from the significance of constructing a dining environment which fulfils the requirements of different students, staff and faculties. The site of the canteen mainly affects its customer traffic and accessibility making it significant to take account of multiple criteria and sub-criteria as location, size, water supply, electricity, waste management, safety and compliance etc. By initiating a Multi-criteria Decision-making approach, this paper targets to systematically configure the best suitable location for canteen in an educational institution. Finally, the research result will contribute to the institution’s target for constructing a canteen in the optimum location improving the overall campus environment.

1.4 Research outline

In this section, we develop the study's research outline based on the above study and motivation. The primary purpose of this study is to determine the proper and ideal site selection for a canteen on a university campus. There are five various criteria and three different locations are used as alternatives for evaluation. Two MCDM techniques, i.e., CRITIC and COPRAS are selected as optimization tools and Triangular Neutrosophic number (TNN) are appraised as ambiguous tools. Data are gathered in an impartial way and numerically computed the result on it. Lastly, sensitivity analysis were conducted in four different cases.

1.5 Structure of this paper

This portion explains the framework of this research. The introduction of this work is pointed out in Section 1. Further, Section 2 clarifies the literature survey of this paper. Then, the preliminaries of mathematical tools and multi-criteria decision making (MCDM) techniques are described in Section 3 and Section 4, respectively. Criteria and alternative selection are shortly elaborated in Section 5 and Section 6, particularly. The model structure and data collection are enumerated in Section 7. Additionally, Section 8 covered the numerical illustration and discussion. The sensitivity analysis of the work is fully described in Section 9 with four different cases. Therefore, the research implications are mentioned in Section 10. Finally, conclusions and future research scope are elucidated in Section 11.

2. Literature survey of this study

This section briefly discusses the background of this study. First, we short literature on the Canteen selection studies and then survey on the various articles related to neutrosophic fuzzy numbers, their evaluation and applications. Additionally, we conducted a short survey on the MCDM methods and their utilization in real life.

2.1 Background on Canteen related paper

Canteens are crucial in a variety of contexts, including schools, colleges, universities, workplaces, etc., as they offer food and drink, which mainly support leading healthy lifestyles and create a social interaction (Sholihah et al., 2020). It also offers students, staff and colleagues a get together place where they can trade any ideas, do important discussions and eat together in this informal environment. In this paper, we work on the site selection problem of the canteen on a university campus. To consider the ideal site for a canteen or a canteen in an institutional place, many researchers used various techniques to take out useful information, structure the problems and give a final decision. In this section, we discuss some of the papers that described the canteen related research in details. Table 1 describes the recent studies on the canteen and Table 2 covers the site selection of the canteen in an educational institute.

Table 1. Some studies on Canteen related paper

Author	Application Area
Zhao et al. (2020)	Apply to select the site of taxi canteen applying taxi trajectory data
Kadam et al. (2024)	Canteen automation system
Li (2019)	Apply on the pattern and perfect design of community aged persons’ canteen
Fu and Wang (2020)	Evaluation of unit canteen suppliers based on Entropy method and AHP
Mohamad et al. (2021)	Mobile school canteen food ordering system

Table 2. Studies on Canteen site selection in educational institute

Author	Application Area
Sholihah et al. (2019)	Evaluated the canteen amenities in educational institutions with the help of Force Field analysis process
Jannah and Rahayu (2023)	Application of canteen selection for Bunga Bangsa Cirebon students
Navelkar et al. (2022)	Canteen management system
Wyse et al. (2019)	Application of an online canteen ordering process in Australian primary schools
Schneider et al. (2021)	Apply of the environmental intervention in a university canteen

2.2 Background of Mathematical tool

Here, we use the Triangular Neutrosophic Number (TNN) (Edalatpanah, 2020) to obtain an accurate presentation of this study in the fuzzy environment throughout the decision-making process. Even in an uncertain environment, it is feasible to effectively convey ambiguity and uncertainty by exhibiting decision-making ability in various contexts and for various reasons (Hussain and Ullah, 2024; Božanić et al., 2023). There are many numerous fields where fuzzy sets are used, such as, solving integral equations, solving differential equations, series solutions and many more. Fuzzy numbers and neutrosophic numbers are also applied to solve differential equations, difference equations, integral equations and many more computational problems (Alamin et al., 2025; Gazi et al., 2024; Singh et al., 2024a; Singh et al., 2024b; Singh et al., 2024c). A brief literature review on fuzzy numbers and triangular fuzzy numbers (TFN) is described in Table 3.

Table 3. Literature review on fuzzy numbers, triangular fuzzy numbers

Author	Fuzzy environment	Application Area
Pathinathan et al. (2015)	Pentagonal fuzzy numbers	Various types of fuzzy numbers and its properties
Kumar et al. (2022)	Generalized fuzzy numbers	Applications of generalized fuzzy numbers
Gani and Assarudeen (2012)	Triangular fuzzy number	Apply on fuzzy linear programming Problem
Arora and Naithani (2023)	Triangular fuzzy number	Application on distance measures
Mondal et al. (2019)	Nonlinear triangular intuitionistic fuzzy numbers	Application in linear integral equation
Mondal and Roy (2015)	Triangular intuitionistic fuzzy number	Application of the system of differential equation with initial value
Wang et al. (2016)	Triangular fuzzy number	Knowledge management performance evaluation (KMPE) problem is solved by systematic method
Gazi et al. (2025)	Pentagonal fuzzy number	Apply to find the most important criteria in women's empowerment for sports sector
Singh et al. (2024c)	Fuzzy sets and fuzzy numbers	Apply to find the solution of a fuzzy system of the linear equation under several fuzzy difference
Alamin et al. (2025)	Fuzzy sets	Apply to solve the first order non-homogenous fuzzy difference equation

In this portion, we describe the short literature review on several types of fuzzy numbers, which are very helpful for this work. The clear review of neutrosophic numbers and triangular neutrosophic numbers (TNNs) are also discoursed in Table 4.

Table 4. Literature review on neutrosophic numbers (NNs) and TNNs

Author	Fuzzy environment	Application Area
Muthulakshmi et al. (2022)	Neutrosophic numbers	Describe the properties
Bhowmik and Pal (2009)	Intuitionistic sets and neutrosophic sets	Some explanation about Intuitionistic Neutrosophic Set
Chakraborty (2020)	Pentagonal neutrosophic Numbers	Application in networking problem with new score function
Smarandache (2014)	Neutrosophic set statistics	Description of neutrosophic statistics
Hamza et al. (2021)	Triangular neutrosophic Sets	Triangular Neutrosophic Topology
Edalatpanah (2020)	Triangular neutrosophic Numbers	Application on linear programming
Mohamed et al. (2017)	Triangular fuzzy number	Application on the critical path Problem

2.3 Literature on MCDM methodologies

Multi-criteria decision-making (MCDM) is the process of making decisions when faced with various conflicting criteria (Madić et al., 2024). It is actually finding the criteria weight and ranking the alternatives for solving the given problem. The ideal method for handling the uncertain environment in this decision-making procedure is to apply the MCDM method (Tešić and Khalilzadeh, 2024). It utilized the complete decision-making problems very useful manner, like Girl's hostel site selection in an educational institute by Biswas et al. (2025a), build a restaurant beside highway considering their specific needs by Biswas et al. (2025b) and so on. We apply the Criteria Importance Through Intercriteria Correlation (CRITIC) (Kamali Saraji et al., 2021) and he complex proportional assessment method (COPRAS) (Mishra et al., 2022) to select the ideal site for a university canteen in this work. Fuzzy CRITIC is used to address ambiguity in the given weights and calculate alternatives. Besides, COPRAS is a Ranking MCDM method. We give a brief overview of some relevant research work for CRITIC and COPRAS processes in different fuzzy environments below Table 5.

Table 5. A literature review on neutrosophic numbers (NNs) and TNNs

Author	Uncertainty	MCDM methods	Application Area
Kamali Saraji et al. (2021)	Fermatean fuzzy set	CRITIC & COPRAS	Application on evaluating the challenges to industry 4.0 and adoption for a sustainable digital transformation
Saraji et al. (2021)	Pythagorean fuzzy number	SWARA, CRITIC & COPRAS	Calculating the barriers to developing business model innovation for sustainability
Ahmadsaraei et al. (2022)	Fuzzy sets	Delphi, CRITIC & COPRAS	Application on sustainable supply chain risk in food packaging industry
Akram et al. (2022)	Fermatean fuzzy Sets	COPRAS	Apply to extend the COPRAS process Description of neutrosophic statistics
Mishra et al. (2022)	IV hesitant Fermatean fuzzy sets	COPRAS	Application in selecting desalination technology

3. Preliminaries of Mathematical Tools

This section discussed the preliminaries of the mathematical tools in detail. First, we are talking about the fuzzy set (Gazi et al., 2024) and its properties and then studies on neutrosophic sets (Pamucar et al., 2020) and their properties.

3.1 Fuzzy sets and fuzzy numbers

Fuzzy set invented by Lotfi A. Zadeh (Zadeh, 1965) in 1965. The definition and basic properties of fuzzy sets are described as follows:

Definition 1. [Fuzzy Set] (Singh et al., 2024b)

Let us choose, p is an arbitrary element of $\tilde{J}$ where P is a universal set. Therefore, the fuzzy set $\tilde{J}$ on P is defined as follows,

$$\tilde{J} = \left\{\left(p, \mu_{\tilde{J}}(p)\right) : p \in P\right\} \quad (1)$$

where, the membership value of the element p in $\tilde{J}$ is $\mu_{\tilde{J}}(p)P \rightarrow [0,1]$.

Example 1. Let the reference set of girls in college is $Q = \{p_1, p_2, p_3, p_4, p_5\}$. Using "good" as a fuzzy term, consider $\widetilde{K}$ to be the fuzzy set of "good" girls in college. Then, the required set is,

$\widetilde{K} = \{(p_1, 0.3), (p_2, 0.5), (p_3, 1), (p_4, 0.9), (p_5, 0.7)\}$

where, the p_1 office colleague is young of 0.3 range and so on.

Definition 2. [Fuzzy Number] (Singh et al., 2024a)

The following requirements must be expressed for a fuzzy set $\tilde{I}$ on the set of real numbers $\mathbb{R}$, such that

I. $\tilde{I}$ need to be the normal fuzzy set, i.e., there exists an element, $a \in \mathbb{R}$ such that $\mu_{\tilde{I}}(a) = 1$.

II. ${}^{\alpha}\tilde{I}$ must be a closed interval for every $\alpha \in (0,1]$, where, ${}^{\alpha}\tilde{I} = \{a: \mu_{\tilde{I}}(a) \geq \alpha\}$ is closed.

III. ${}^{\alpha}\tilde{I}$ needs to be a convex fuzzy set, i.e., $\mu_{\tilde{I}}(\lambda a_1 + (1-\lambda)a_2) \geq \max\{\mu_{\tilde{I}}(a_1), \mu_{\tilde{I}}(a_2)\}$; $\forall a_1, a_2 \in \tilde{I}$ and $\lambda \in [0,1]$.

IV. $\tilde{I}$ should be bounded support within a specific range.

V. The membership function of $\tilde{I}$ must be piecewise continuous.

Example 2. Consider that Puja scored "Good" marks in the exam. The word "Good" can not express her exact score and the term "Good" differs from person to person. So, we can apply the fuzzy number concept by selecting this as an object. Therefore, from 0 ("Not good in fuzzy concept) to 1 ("Good" in fuzzy concept) is the membership function of the mentioned object.

3.2 Neutrosophic sets and Neutrosophic numbers

The neutrosophic set was first introduced by Florentin Smarandache (Smarandache, 2005) in 2005. In the neutrosophic set, there are three membership functions, whereas the fuzzy set has only one. The definition and basic properties are discussed as follows:

Definition 3. [Neutrosophic Fuzzy Set] (Mishra et al., 2024)

Let us choose X be a universal set of discourse and a single valued neutrosophic fuzzy set $\tilde{B}$ defined as,

$$\tilde{B} = \left\{\left(a, u_{\tilde{B}}(a), v_{\tilde{B}}(a), w_{\tilde{B}}(a)\right): a \in X\right\} \quad (2)$$

where $u_{\tilde{B}}(a)$, $v_{\tilde{B}}(a)$ and $w_{\tilde{B}}(a)$ are the degree of membership, the degree of indeterministic and the degree of non-membership functions, respectively and $u_{\tilde{B}}(a), v_{\tilde{B}}(a), w_{\tilde{B}}(a): X \to [0,1]$ where $a \in X$ is an arbitrary element. The primary condition is that $0 \leq u_{\tilde{B}}(a), +v_{\tilde{B}}(a) + w_{\tilde{B}}(a) \leq 3$.

Remark 1. If the single valued neutrosophic logic is $\left(u_{\tilde{B}}(a), v_{\tilde{B}}(a), w_{\tilde{B}}(a)\right)$, then

a) If the three components are dependent, then $0 \leq u_{\tilde{B}}(a), +v_{\tilde{B}}(a) + w_{\tilde{B}}(a) \leq 1$.

b) If the two elements are dependent and the third is independent, then $0 \leq u_{\tilde{B}}(a), +v_{\tilde{B}}(a) + w_{\tilde{B}}(a) \leq 2$.

c) If all three elements are independent, then $0 \leq u_{\tilde{B}}(a), +v_{\tilde{B}}(a) + w_{\tilde{B}}(a) \leq 3$.

Definition 4. [Neutrosophic Number (NN)]

Let, $\tilde{A}$ be a single valued neutrosophic fuzzy set on $\mathbb{R}$, the set of real numbers is said to be a neutrosophic fuzzy number if it fulfils the following conditions,

(i) $\tilde{A}$ is normal if $\exists a_0 \in \mathbb{R}$, such that $u_{\tilde{A}}(a_0) = 1$, where $v_{\tilde{A}}(a_0) = w_{\tilde{A}}(a_0) = 0$.

(ii) $\tilde{A}$ is convex set for membership function $u_{\tilde{A}}(a)$, such that $u_{\tilde{A}}(\gamma a_1 + (1-\gamma)a_2) \geq \min\{u_{\tilde{A}}(a_1), u_{\tilde{A}}(a_2)\}$; $\forall a_1, a_2 \in \mathbb{R}$ and $\gamma \in [0,1]$.

(iii) $\tilde{A}$ is convex set for indeterministic function $v_{\tilde{A}}(a)$, such that $v_{\tilde{A}}(\gamma a_1 + (1-\gamma)a_2) \leq \min\{v_{\tilde{A}}(a_1), v_{\tilde{A}}(a_2)\}$; $\forall a_1, a_2 \in \mathbb{R}$ and $\gamma \in [0,1]$.

(iv) $\tilde{A}$ is convex set for non-membership function $w_{\tilde{A}}(a)$, such that $w_{\tilde{A}}(\gamma a_1 + (1-\gamma)a_2) \leq \min\{w_{\tilde{A}}(a_1), w_{\tilde{A}}(a_2)\}$; $\forall a_1, a_2 \in \mathbb{R}$ and $\gamma \in [0,1]$.

3.3 Triangular Neutrosophic Number (TNN)

This section describes the triangular neutrosophic numbers (TNNs) (Das et al., 2020) and their characteristics from different viewpoints. TNNs are applied in various fields to capture the uncertainty and vagueness of the systems and express the model more specifically. This study considers TNNs as a mathematical tool to deal with the uncertainty of the system.

Definition 5. [Triangular Neutrosophic Number (TNN)]

A single valued Triangular Neutrosophic Number (TNN) $\tilde{T} = \langle (a, u_{\tilde{T}}(a), v_{\tilde{T}}(a), w_{\tilde{T}}(a)); (d_1, d_2, d_3; X_N, Y_N, Z_N) \rangle$ is a subset of neutrosophic fuzzy number in $\mathbb{R}$ with the base of convex membership $(u_{\tilde{T}}(a))$, indeterministic $(v_{\tilde{T}}(a))$ and non-membership $(w_{\tilde{T}}(a))$ functions which is denoted by,

$$u_{\tilde{T}}(a) = \begin{cases} X_N \frac{a-d_1}{d_2-d_1} & ;where\ d_1 \le a < d_2 \\ X_N & ;where\ a = d_2 \\ X_N \frac{d_3-a}{d_3-d_2} & ;where\ d_2 < a \le d_3 \\ 0 & ;otherwise \end{cases} \tag{3}$$

,

$$v_{\tilde{T}}(a) = \begin{cases} \frac{(d_2-a)+(a-d_1)Y_N}{d_2-d_1} & ;where\ d_1 \le a < d_2 \\ Y_N & ;where\ a = d_2 \\ \frac{(a-d_2)+(d_3-a)Y_N}{d_3-d_2} & ;where\ d_2 < a \le d_3 \\ 0 & ;otherwise \end{cases} \tag{4}$$

and

$$w_{\tilde{T}}(a) = \begin{cases} \frac{(d_2-a)+(a-d_1)Z_N}{d_2-d_1} & ;where\ d_1 \le a < d_2 \\ Z_N & ;where\ a = d_2 \\ \frac{(a-d_2)+(d_3-a)Z_N}{d_3-d_2} & ;where\ d_2 < a \le d_3 \\ 0 & ;otherwise \end{cases} \tag{5}$$

where $0 \le u_{\tilde{T}}(a) + v_{\tilde{T}}(a) + w_{\tilde{T}}(a) \le 1$, $d_1 \le d_2 \le d_3$, $0 \le X_N, Y_N, Z_N \le 1$ and $a \in \mathbb{R}$.

Example 3. Consider two TNNs define on a set of universal set $\mathbb{R}$ and describe as $\tilde{S}_1 = \langle \left(a, u_{\tilde{S}_1}(a), v_{\tilde{S}_1}(a), w_{\tilde{S}_1}(a); (6,9,11; 0.65,0.05,0.25)\right) \rangle$ and $\tilde{S}_2 = \langle \left(a, u_{\tilde{S}_2}(a), v_{\tilde{S}_2}(a), w_{\tilde{S}_2}(a); (14,16,19; 0.60,0.15,0.20)\right) \rangle$. Then the TNNs $\tilde{S}_1$ and $\tilde{S}_2$ defined on $\mathbb{R}$ and the membership functions are $u_{\tilde{S}_1}(a)$ and $u_{\tilde{S}_2}(a)$, indeterministic functions are $v_{\tilde{S}_1}(a)$ and $v_{\tilde{S}_2}(a)$ and non-membership functions are $w_{\tilde{S}_1}(a)$ and $w_{\tilde{S}_2}(a)$, respectively.

The geometric structure of the triangular neutrosophic number (TNN) is presented in Figure 1.

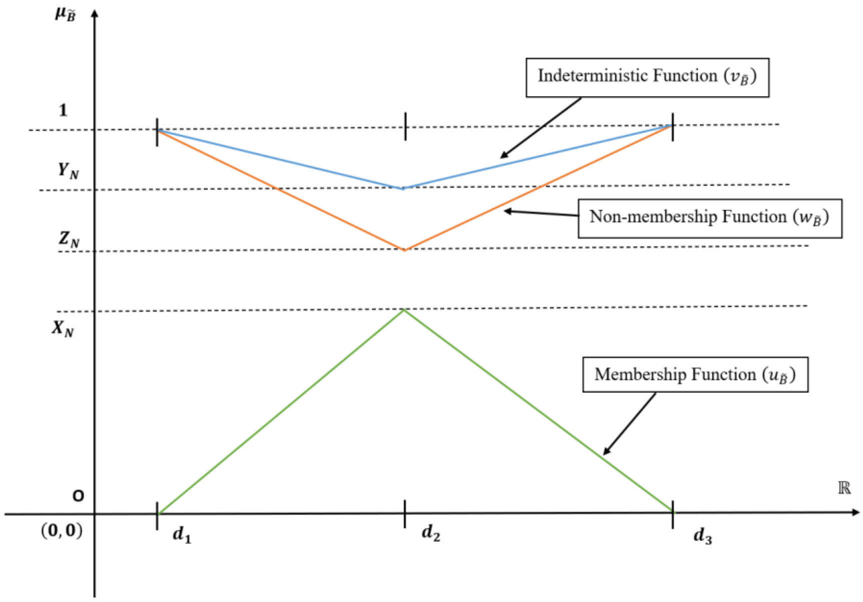

Figure 1. Graphical structure of triangular neutrosophic number (TNN)

Definition 6. [Arithmetic operations on TNNs]

Consider two single valued triangular neutrosophic numbers (TNNs) defined on a universal set of discourse $\mathbb{R}$ and define as $\tilde{P} =< \left(a, u_{\tilde{P}}(a), v_{\tilde{P}}(a), w_{\tilde{P}}(a)\right); (d_1, d_2, d_3; X_M, Y_M, Z_M) >$ and $\tilde{Q} = < \left(a, u_{\tilde{Q}}(a), v_{\tilde{Q}}(a), w_{\tilde{Q}}(a)\right); (e_1, e_2, e_3; X_N, Y_N, Z_N) >$. Further, assume $\lambda(> 0)$ be a scalar. Then, the arithmetic operations on TNNs $\tilde{P}$ and $\tilde{Q}$ are described as

A. Addition of two TNNs:

$$\begin{aligned}\tilde{P} \oplus \tilde{Q} &=< \left(a, u_{\tilde{P}}(a), v_{\tilde{P}}(a), w_{\tilde{P}}(a)\right); (d_1, d_2, d_3; X_M, Y_M, Z_M) > \\ &\quad \oplus< \left(a, u_{\tilde{Q}}(a), v_{\tilde{Q}}(a), w_{\tilde{Q}}(a)\right); (e_1, e_2, e_3; X_N, Y_N, Z_N) > \\ &=< \left(a, u_{\tilde{P}\oplus\tilde{Q}}(a), v_{\tilde{P}\oplus\tilde{Q}}(a), w_{\tilde{P}\oplus\tilde{Q}}(a)\right); \\ &\quad (d_1 + e_1, d_2 + e_2, d_3 + e_3; \max\{X_M, X_N\}, \min\{Y_M, Y_N\}, \min\{Z_M, Z_N\}) > \end{aligned} \tag{6}$$

B. Subtraction of two TNNs:

$$\begin{aligned}\tilde{P} \ominus \tilde{Q} &=< \left(a, u_{\tilde{P}}(a), v_{\tilde{P}}(a), w_{\tilde{P}}(a)\right); (d_1, d_2, d_3; X_M, Y_M, Z_M) > \\ &\quad \ominus< \left(a, u_{\tilde{Q}}(a), v_{\tilde{Q}}(a), w_{\tilde{Q}}(a)\right); (e_1, e_2, e_3; X_N, Y_N, Z_N) > \\ &=< \left(a, u_{\tilde{P}\ominus\tilde{Q}}(a), v_{\tilde{P}\ominus\tilde{Q}}(a), w_{\tilde{P}\ominus\tilde{Q}}(a)\right); \\ &\quad (d_1 - e_3, d_2 - e_2, d_3 - e_1; \min\{X_M, X_N\}, \max\{Y_M, Y_N\}, \max\{Z_M, Z_N\}) > \end{aligned} \tag{7}$$

C. Scalar Multiplication of TNN:

$$\begin{aligned}\lambda\tilde{P} = \lambda \times \tilde{P} &= \lambda \times< \left(a, u_{\tilde{P}}(a), v_{\tilde{P}}(a), w_{\tilde{P}}(a)\right); (d_1, d_2, d_3; X_M, Y_M, Z_M) > \\ &=< \left(a, u_{\lambda\tilde{P}}(a), v_{\lambda\tilde{P}}(a), w_{\lambda\tilde{P}}(a)\right); (\lambda d_1, \lambda d_2, \lambda d_3; X_M, Y_M, Z_M) > \end{aligned} \tag{8}$$

where $\lambda(> 0)$ be a positive scalar number.

D. Multiplication of two TNNs:

$$\begin{aligned}\tilde{P} \otimes \tilde{Q} &=< \left(a, u_{\tilde{P}}(a), v_{\tilde{P}}(a), w_{\tilde{P}}(a)\right); (d_1, d_2, d_3; X_M, Y_M, Z_M) > \\ &\quad \otimes< \left(a, u_{\tilde{Q}}(a), v_{\tilde{Q}}(a), w_{\tilde{Q}}(a)\right); (e_1, e_2, e_3; X_N, Y_N, Z_N) > \\ &=< \left(a, u_{\tilde{P}\otimes\tilde{Q}}(a), v_{\tilde{P}\otimes\tilde{Q}}(a), w_{\tilde{P}\otimes\tilde{Q}}(a)\right); \\ &\quad (d_1 e_1, d_2 e_2, d_3 e_3; \max\{X_M, X_N\}, \min\{Y_M, Y_N\}, \min\{Z_M, Z_N\}) > \end{aligned} \tag{9}$$

3.4 De-neutrosophic method

The de-neutrosophic method is the method of evaluating a single number from the input of a combined neutrosophic number. Its main benefit is to transform the outcomes of neutrosophic estimation into a crisp output since there are no order relations in the fuzzy or neutrosophic numbers. For a given triangular neutrosophic number (TNN), various de-neutrosophic processes may provide various de-neutrosophic values. Different kinds of de-neutrosophic techniques exist, but here we propose a Removal Area (RA) method.

Definition 7. Let us choose $\tilde{Q} =< \left(a, u_{\tilde{Q}}(a), v_{\tilde{Q}}(a), w_{\tilde{Q}}(a)\right); (e_1, e_2, e_3; X_N, Y_N, Z_N) >$ be a TNN define on $\mathbb{R}$. Then, the proposed de-neutrosophic value of the TNN $\tilde{Q}$ by total area covered method is denoted by $D(\tilde{Q})$ and defined as

$$\begin{aligned} D(\tilde{Q}) &= \left[\frac{e_1 + 2 \times e_2 + e_3}{5}\right] \times (3 \times X_N - Y_N - 2 \times Z_N) \\ &= \left[\tfrac{e_1 + 2\times e_2 + e_3}{5}\right](3X_N - Y_N - 2Z_N) \end{aligned} \tag{10}$$

Example 4. Consider, two TNNs $\tilde{A}_1 = \{6,9,11; 0.65,0.05,0.25\}$ and $\tilde{A}_2 = \{14,16,19; 0.60,0.15,0.20\}$ define on the universal set of discourse $\mathbb{R}$. Therefore, the de-neutrosophic values of $\tilde{A}_1$ and $\tilde{A}_2$ are determined as

$$D(\tilde{A}_1) = \left[\frac{6 + 2 \times 9 + 11}{5}\right] \times (3 \times 0.65 - 0.05 - 2 \times 0.25)$$

$$= \frac{35}{5} \times (1.4)$$
$$= 9.8$$

and

$$D(\tilde{A}_2) = \left[\frac{14 + 2 \times 16 + 19}{5}\right] \times (3 \times 0.60 - 0.15 - 2 \times 0.20)$$
$$= \frac{65}{5} \times (1.25)$$
$$= 16.25$$

4. Proposed methodology

This section discussed the mathematical procedure of the two used Multi-Criteria Decision-Making (MCDM) methods, namely CRITIC and COPRAS, in triangular neutrosophic number (TNN) environments. MCDM (Momena et al., 2024) is a popular optimisation technique for dealing with multiple conflicting criteria and sub-criteria. First, describe the CRITIC methodology (Kamali Saraji et al., 2021) to evaluate the weight of criteria and further express the COPRAS methodology (Akram et al., 2022) to calculate the ranking of the sites.

4.1 Weight calculation method: Criteria Importance Through Inter-criteria Correlation (CRITIC) method

In 1995, Diakoulaki et al. (1995) first represented the Criteria Importance Through Inter-criteria Correlation (CRITIC) method. It is an objective technique for analysing the weights of factors. With this important process, we may determine the mutual relevance of criteria and the correlations between them. When ambiguity occurs, Criteria Importance Through Inter-criteria Correlation (CRITIC) plays an important role in decision making in the MCDM process. The flowchart of the CRITIC technique is formulated in Figure 2.

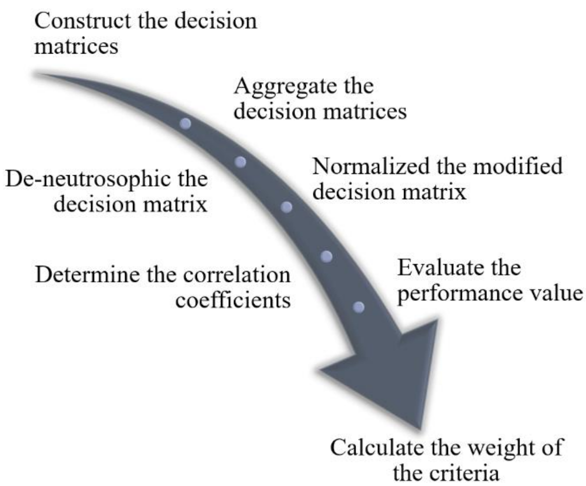

Figure 2. Structural flowchart of the CRITIC method

In this paper, we choose the number of criteria is γ and for every criterion n $(n = 1,2, \dots, \gamma)$, there is κ_n number of sub-criteria connected. Moreover, δ number of alternatives are considered here for ranking. And, d number of decision makers (DMs) gave their valuable and wise opinions based on these. Here, the decision matrix is formed by αth decision maker and it is based on their decision, which is defined by $\widetilde{D}_\alpha$, where $\alpha = 1,2, \dots, d$. The following steps are discussed for the CRITIC method, as follows:

A. Formulation of a decision matrix in terms of the Double Parametric form of Triangular Neutrosophic Numbers:

Every decision maker gives their decision in terms of linguistics and after that, it is converted to TNN. So, the decision matrix $\left(\widetilde{D}_\alpha\right)$ for the selected criteria is denoted as follows,

$$\widetilde{D}_\alpha = \begin{bmatrix} \left(\tilde{B}_{11}\right)_\alpha & \left(\tilde{B}_{12}\right)_\alpha & \cdots & \left(\tilde{B}_{1n}\right)_\alpha & \cdots & \left(\tilde{B}_{1\gamma}\right)_\alpha \\ \left(\tilde{B}_{21}\right)_\alpha & \left(\tilde{B}_{22}\right)_\alpha & \cdots & \left(\tilde{B}_{2n}\right)_\alpha & \cdots & \left(\tilde{B}_{2\gamma}\right)_\alpha \\ \vdots & \vdots & \ddots & \cdots & \ddots & \vdots \\ \left(\tilde{B}_{m1}\right)_\alpha & \left(\tilde{B}_{m2}\right)_\alpha & \cdots & \left(\tilde{B}_{mn}\right)_\alpha & \cdots & \left(\tilde{B}_{m\gamma}\right)_\alpha \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \left(\tilde{B}_{\delta 1}\right)_\alpha & \left(\tilde{B}_{\delta 2}\right)_\alpha & \cdots & \left(\tilde{B}_{\delta n}\right)_\alpha & \cdots & \left(\tilde{B}_{\delta\gamma}\right)_\alpha \end{bmatrix}_{\delta\times\gamma} \tag{11}$$

where each entry is a TNN element that perhaps in comparison matrices $\widetilde{D}_\alpha$.

Equation (11) can also be described as bellow,

$$\widetilde{D}_\alpha = \left[\left(\tilde{B}_{mn}\right)_\alpha\right]_{\delta\times\gamma} \tag{12}$$

Where $\widetilde{D}_\alpha$ is $\delta \times \gamma$ order matrix and $n = 1,2,\dots,\gamma$; $m = 1,2,\dots,\delta$. The is a linguistic phrase $\left(\tilde{B}_{mn}\right)_\alpha$, that given by δth DMs, which converts into TNN. These terms are given on the basis of mth alternative and nth criteria.

By the similar way, the decision matrix $\left(\widetilde{D}_\alpha^{s_n}\right)$ for sub-criteria for every criteria n where $n = 1,2,\dots,\gamma$ is define as,

$$\widetilde{D}_\alpha^{s_n} = \begin{bmatrix} \left(\tilde{B}_{11_n}\right)_\alpha & \left(\tilde{B}_{12_n}\right)_\alpha & \cdots & \left(\tilde{B}_{1s_n}\right)_\alpha & \cdots & \left(\tilde{B}_{1\kappa_n}\right)_\alpha \\ \left(\tilde{B}_{21_n}\right)_\alpha & \left(\tilde{B}_{22_n}\right)_\alpha & \cdots & \left(\tilde{B}_{2s_n}\right)_\alpha & \cdots & \left(\tilde{B}_{2\kappa_n}\right)_\alpha \\ \vdots & \vdots & \ddots & \cdots & \ddots & \vdots \\ \left(\tilde{B}_{m1_n}\right)_\alpha & \left(\tilde{B}_{m2_n}\right)_\alpha & \cdots & \left(\tilde{B}_{ms_n}\right)_\alpha & \cdots & \left(\tilde{B}_{m\kappa_n}\right)_\alpha \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \left(\tilde{B}_{\delta 1_n}\right)_\alpha & \left(\tilde{B}_{\delta 2_n}\right)_\alpha & \cdots & \left(\tilde{B}_{\delta s_n}\right)_\alpha & \cdots & \left(\tilde{B}_{\delta\kappa_n}\right)_\alpha \end{bmatrix}_{\delta\times\kappa_n} \tag{13}$$

Here, each entry is also a TNN element that perhaps in comparison matrices $\widetilde{D}_\alpha^{s_n}$.

The Equation (13) can also be described as follows,

$$\widetilde{D}_\alpha^{s_n} = \left[\left(\tilde{B}_{ms_n}\right)_\alpha\right]_{\delta\times\kappa_n} \tag{14}$$

Here, for every criteria n; $s_n = 1_n, 2_n, \dots, \kappa_n$, $m = 1,2,\dots,\delta$, $\alpha = 1,2,\dots,d$ and $\widetilde{D}_\alpha^{s_n}$ is a $\delta \times \kappa_n$ order matrix.

Then, in Table 6 αth DMs are given the input $\left(\tilde{B}_{ms_n}\right)_\alpha$ on the basis of mth alternative and s_nth criteria and it shows as,

$$\begin{aligned}\left(\tilde{B}_{ms_n}\right)_\alpha &= \left\{(d_1, d_2, d_3; X_N, Y_N, Z_N)_{ms_n}\right\}_\alpha \\ &= \left\{(d_1)_{ms_n}^\alpha, (d_2)_{ms_n}^\alpha, (d_3)_{ms_n}^\alpha; (X_N)_{ms_n}^\alpha, (Y_N)_{ms_n}^\alpha, (Z_N)_{ms_n}^\alpha\right\}\end{aligned} \tag{15}$$

B. Aggregate the above mentioned decisions matrices:

In this step, all decision matrices are aggregated and it is converted into a single decision matrix. The aggregated matrix is

$$\begin{aligned}\widetilde{D}_\alpha &= \left[\left(\tilde{B}_{mn}\right)\right]_{\delta\times\gamma} \\ &= \left[(d_1, d_2, d_3; X_N, Y_N, Z_N)_{mn}\right]_{\delta\times\gamma} \\ &= \left[((d_1)_{mn}, (d_2)_{mn}, (d_3)_{mn}; (X_N)_{mn}, (Y_N)_{mn}, (Z_N)_{mn})\right]_{\delta\times\gamma}\end{aligned} \tag{16}$$

when $m = 1, 2, \dots, \delta$, $n = 1, 2, \dots, \gamma$ and each entry of Equation (16) can simplify by the following way, i.e.,

$$\begin{cases} (d_1)_{mn} = \min_{\alpha=1,2,\dots,d} (d_1)^{\alpha}_{mn} \\ (d_2)_{mn} = \sqrt[d]{\prod_{\alpha=1}^{d} (d_2)^{\alpha}_{mn}} \\ (d_3)_{mn} = \max_{\alpha=1,2,\dots,d} (d_3)^{\alpha}_{mn} \\ (X_N)_{mn} = \min_{\alpha=1,2,\dots,d} (X_N)^{\alpha}_{mn} \\ (Y_N)_{mn} = \max_{\alpha=1,2,\dots,d} (Y_N)^{\alpha}_{mn} \\ (Z_N)_{mn} = \max_{\alpha=1,2,\dots,d} (Z_N)^{\alpha}_{mn} \end{cases} \tag{17}$$

For perfect numerical analysis, choose this decision matrix only for criteria. Similar numerical computations are evaluated to find the sub-criteria weight as usual.

C. De-neutrosophic the aggregated decision matrices:

Compute the de-neutrosophic aggregated comparison matrix (D) from the considered aggregated comparison matrix $(\widetilde{D})$. So, the value of de-neutrosophic aggregated comparison matrix D is denoted bellow,

$$D = [(B_{mn})]_{\delta\times\gamma} \tag{18}$$

where, the de-neutrosophic value of TNN is B_{mn} and $\tilde{B}_{mn}$ evaluated by de-neutrosophic formula mentioned in Equation (10) and $m = 1, 2, \dots, \delta$, $n = 1, 2, \dots, \gamma$.

D. Normalization of the considered Decision Matrix:

We calculate the Normalized decision matrix $(\widetilde{D}_{nr})$ from the de-neutrosophic valued decision matrix (D). For this, we apply the formula given below,

$$\tilde{B}'_{mn} = \frac{\tilde{B}_{mn} - \tilde{B}_n^{worst}}{\tilde{B}_n^{best} - \tilde{B}_n^{worst}} \tag{19}$$

In Equation (19), we show that,

$$\begin{cases} \tilde{B}_n^{best} = \max_{m=1,2,\dots,\delta} \tilde{B}_{mn} \\ \tilde{B}_n^{worst} = \min_{m=1,2,\dots,\delta} \tilde{B}_{mn} \end{cases}$$

E. Computing the Standard deviation of each criteria:

For each criteria, the standard deviation σ_n is developed by using the Equation (20), as follows,

$$\sigma_n = \sqrt{\frac{\sum_{n=1}^{\gamma} (\tilde{B}_n - \overline{\tilde{B}_n})}{\gamma - 1}} \tag{20}$$

In the above equation, $\overline{\tilde{B}_n}$ is the population mean; γ is the size of the population, which is also known as the number of criteria and $n = 1,2,\dots,\gamma$.

F. Finding the linear Correlation coefficient $(\tilde{\theta}_{nn'})$ between the criteria c_n and criteria $c_{n'}$:

Now, we will consider the symmetric matrix of $\gamma \times \gamma$ order with the elements $\tilde{B}'_n$. It is the linear correlation coefficient between the vectors $\tilde{B}_n$ and $\tilde{B}'_n$ and the required Correlation coefficient between the criteria c_n and $c_{n'}$ which is denoted by $\tilde{\theta}_{nn'}$.

G. Determine of the conflict created by the criteria:

Using the below given formula, we find the conflict $(\tilde{B}_n)$ created by the criteria n with regard to the choice scenario defined by the remaining criteria, i.e.,

$$\tilde{B}_n = \sum_{n'=1}^{\gamma} (1 - \tilde{\theta}_{nn'}) \tag{21}$$

H. Measuring the information quality:

We determine the quality of the information (Q_n) in relation to each criteria by applying the formula given as,

$$Q_n = \sigma_n \times \tilde{B}_n \tag{22}$$

where σ_n is the Standard deviation of criteria n and $n = 1,2,\dots,\gamma$.

I. Determining the weights of the objects:

The weight of nth criteria is denoted by Q_n^{lw} and defined as,

$$Q_n^{lw} = \frac{Q_n}{\sum_{n=1}^{\gamma} Q_n} \tag{23}$$

Thus, we can evaluate the weight of each criterion for $n = 1,2,\dots,\gamma$.

The above mentioned Equation (23) gives the local weight Q_n^{lw} for the criteria, where $n = 1,2,\dots,\gamma$ and $\left(Q_{s_n}^{lw}\right)$ be the local weight of the sub-criteria for $s_n = 1_n, 2_n, \dots, \kappa_n$, respectively. Therefore, we compute the global weight $\left(Q_n^{gw}\right)$ of the criteria and global weight $\left(Q_{s_n}^{gw}\right)$ of the sub-criteria defined as follows,

$$Q_{s_n}^{gw} = Q_n^{lw} \times Q_{s_n}^{lw} \tag{24}$$

and

$$Q_n^{gw} = \sum_{s_j=1}^{\kappa_n} Q_{s_n}^{gw} \tag{25}$$

where $n = 1,2,\dots,\gamma$ and $s_n = 1_n, 2_n, \dots, \kappa_n$.

4.2 Ranking MCDM method: Complex Proportional Assessment (COPRAS) method

The Complex Proportional Assessment (COPRAS) method was introduced by Zavadskas et al. (1994) in 1994. The fuzzy set integrated with the COPRAS method can make the model more reliable and evaluate the result optimally. This integrated method is used in various real life applications, including the manufacturing sector (Kamali Saraji et al., 2021), upgrade business model (Saraji et al., 2021), adapting technology (Mishra et al., 2022), etc. This study considers the COPRAS method in a neutrosophic environment to express the ambiguity of the system and data set. The neutrosophic COPRAS method has been used in several studies, like upgrading safety in a construction project by Wei et al. (2021), renewable energy production technologies by Hezam et al. (2023) and choosing an Air Carrier for the Hazardous Goods transportation by Boz et al. (2024). The structural flowchart of the COPRAS method is presented in Figure 3.

Figure 3. Diagrammatic framework of the COPRAS methodology

This study considers γ number of criteria and for every criterion n, $(n = 1,2,\dots,\gamma)$ there is κ_n number of sub-criteria associated. Further, δ number of alternatives are taken for ranking and d number of decision makers (DMs) given data for numerical computation. Therefore, the decision matrices for criteria is $\delta \times \gamma$ order and for sub-criteria is $\delta \times (\kappa_1 + \kappa_2 + \cdots + \kappa_n)$ order. Additionally, αth decision makers ($\alpha = 1,2 \ldots, d$) given data in decision matrix is denoted as $\widetilde{D}_\alpha$. The following steps are included in the COPRAS procedure, as follows:

I. Design the decision matrix with TNN by the decision of DMs. They allocate linguistic terms with the help of the factor.

II. After integration, Equation (17) is used to aggregate the point of view of d number of decision makers with the help of the operator.

III. In this step, we construct the weighted normalized matrix with the help of the product of the criteria weight using TNN s.t., Q_n^{gw} from Equation (24) and finally the normalized matrix is,

$$\tilde{u}_{mn} = Q_n^{gw} \times \tilde{B}'_{mn} \tag{26}$$

where, $n = 1,2, \ldots, \gamma$ and $m = 1,2, \ldots, \delta$.

IV. Computation of beneficiary criteria (BC) and non-beneficiary criteria (NBC); these are defined as BC^+ and NBC^-, respectively, i.e.,

$$BC^+ = \Big\{\textstyle\sum_{n=1}^{q}\big((d_1)_{\tilde{u}_{mn}}\big)_n, \sum_{n=1}^{q}\big((d_2)_{\tilde{u}_{mn}}\big)_n, \sum_{n=1}^{q}\big((d_3)_{\tilde{u}_{mn}}\big)_n; \\ \textstyle\sum_{n=1}^{q}\big((X_N)_{\tilde{u}_{mn}}\big)_n, \sum_{n=1}^{q}\big((Y_N)_{\tilde{u}_{mn}}\big)_n, \sum_{n=1}^{q}\big((Z_N)_{\tilde{u}_{mn}}\big)_n\Big\} \tag{27}$$

and

$$NBC^- = \Big\{\textstyle\sum_{n=q+1}^{\gamma}\big((d_1)_{\tilde{u}_{mn}}\big)_n, \sum_{n=q+1}^{\gamma}\big((d_2)_{\tilde{u}_{mn}}\big)_n, \sum_{n=q+1}^{\gamma}\big((d_3)_{\tilde{u}_{mn}}\big)_n; \\ \textstyle\sum_{n=q+1}^{\gamma}\big((X_N)_{\tilde{u}_{mn}}\big)_n, \sum_{n=q+1}^{\gamma}\big((Y_N)_{\tilde{u}_{mn}}\big)_n, \sum_{n=q+1}^{\gamma}\big((Z_N)_{\tilde{u}_{mn}}\big)_n\Big\} \tag{28}$$

where, Equation (26) gives the value of $\big((d_1)_{\tilde{u}_{mn}}\big)_n$, $\big((d_2)_{\tilde{u}_{mn}}\big)_n$, $\big((d_3)_{\tilde{u}_{mn}}\big)_n$, $\big((X_N)_{\tilde{u}_{mn}}\big)_n$, $\big((Y_N)_{\tilde{u}_{mn}}\big)_n$ and $\big((Z_N)_{\tilde{u}_{mn}}\big)_n$. Among all the alternatives, the beneficial attributes and the non-beneficial attributes are denoted by $n = 1,2, \ldots, q$ and $n = q + 1, \ldots, \gamma$, respectively.

In a similar way, we calculate the beneficiary and non-beneficiary sub-criteria for further calculation process.

V. The de-neutrosophication of TNN is done by the process of Equation (10). For the beneficial attributes, the value is S_m^+ and for the non-beneficial attributes, the value is S_m^-, which is evaluated in this step where $m = 1,2, \ldots, \delta$.

VI. Now, computation the below given equation,

$$H_m = S_m^+ \frac{\sum_{m=1}^{\delta}(S_m^-) \times S_{min}^-}{\sum_{m=1}^{\delta}\left(\frac{S_{min}^-}{S_m^-}\right) \times s_m^-} \tag{29}$$

where, δ be the alternatives and $S_{min}^- = \min\{s_m^-: m = 1,2, \ldots, \delta\}$.

VII. Finally, the required value of K_m is,

$$K_m = \frac{H_m}{H_{max}} \times 1005 \tag{30}$$

In this equation, $H_{max} = \{H_m: m = 1,2, \ldots, \delta\}$ and the rank of the alternative comes by depending on the value of K_m.

5. Criteria Selection for Canteen in a University Campus

This section describes the short description of every criterion and sub-criteria. The selection of the location for the canteen in an educational institute is dependent on multiple criteria and sun-criteria. Those criteria and sub-criteria are selected from the detailed literature studies on canteen location selection studies (Sholihah et al., 2020; Jannah and Rahayu, 2023; Navelkar et al., 2022; Wyse et al., 2019; Schneider et al., 2021) and opinions taken from the decision makers (DMs). Figure 4 graphically represents the criteria and sub-criteria of the canteen site selection in the university campus problem. There are five criteria and fourteen sub-criteria are considered for this site selection. The brief discussion on these criteria and sub-criteria are mentioned as follows:

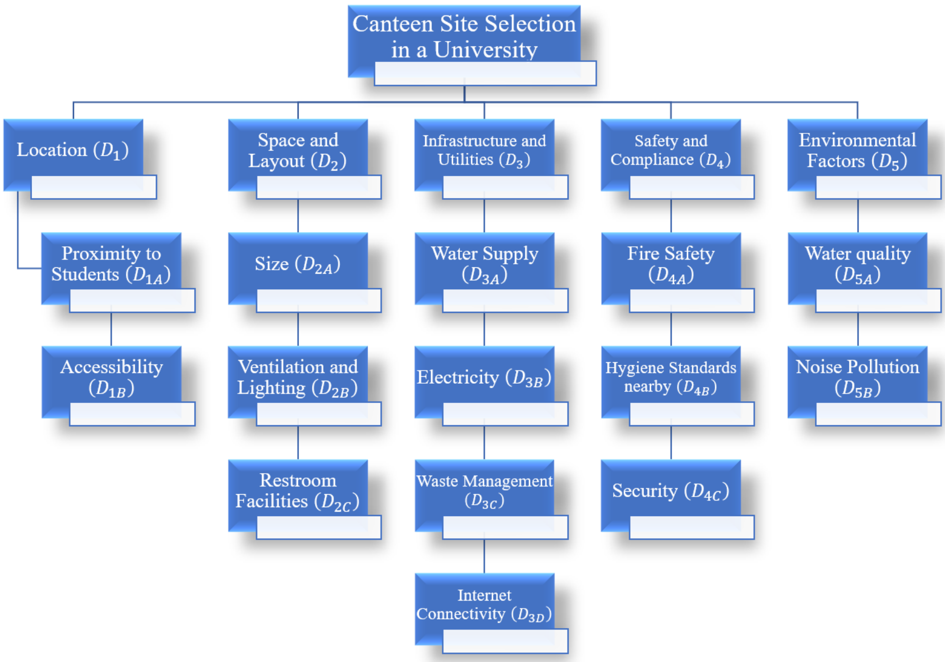

Figure 4. Criteria and sub-criteria of the Canteen site selection study

5.1 Location (D_1)

The site of the canteen should be selected purposively such that students, facilities and all staff can easily access it. The canteen should be located near the academic buildings, library and administrative building for convenience and minimizing duration to reach over there. And more importantly, the canteen must be visible from most parts of the university campus so that customers can easily locate it.

A. Proximity to Students (D_{1A}):

It is an important point to be noted while choosing the site for the canteen in a university as it makes accessibility easy and certain to the pupils. It needs to be positioned close to the educational sector, dormitories as well as common rooms. This will guarantee the maximum use and with enhanced foot traffic. This must ensure to fulfil the student's dietary requirements, increased inter-communication and secure a overall contentment with the features of campus.

B. Accessibility (D_{1B}):

It is a vital factor for opting the place for food court within the university premises. It needs to ensure that all the pupils including the ones with challenges in mobility and other impairment can easily approach the area. Exclusivity, perfection and a sound patronage needs to be certified with smoothly reachable walkways, communication and ramps. The overall welfare of the student's mass can be ensured with a mindful site selection and nature friendly surroundings.

5.2 Space and Layout (D_2)

There should be plenty of space for sitting especially during lunch. The layout should provide clear paths for students to travel inside the canteen. The presence of natural light and well maintained ventilation is also important for comfort.

A. Size (D_{2A}):

It is another crucial feature to be taken into consideration as it ensures proper seating arrangement and service management to fit in enough pupils. A canteen with enough space can effectively control meal distribution times at their peak levels. A spontaneous service providing system can be ensured with various food options to create nurturing surroundings. An enormous potentially varying mass of students can be satisfied with the guarantee of decreased waiting time for the service, swift operations and all together enhanced meal time experiences.

B. Ventilation and Lighting (D_{2B}):

Circulation of fresh air light is a major factor to focus on as it delivers overall comfort and feasible ambience. To prevent odour and heat build, a tolerable environment must be created that can be eliminated through proper ventilation and temperature management. The light should pass in a sufficient amount to ensure the safety and congenial place to eat. Fresh air and light provide both health and security as well as build a satisfying environment altogether.

C. Restroom Facilities (D_{2C}):

Washroom facilities are an important thing that contributes to the students' hygiene and comfort. Clean and well maintained restrooms provide solace to the pupils while devouring. This will elevate the foot traffic as well as foster better sanitary conditions for them. This aligns with affirmative and structured canteen management giving a realistic and gratified food abode.

5.3 Infrastructure and Utilities (D_3)

Satisfactory utilities and arrangements must be present in the canteen side. This should include plenty of water supplies, proper electricity and an organised disposal system of waste. There also should be enough kitchen space to cook a lot of food items.

A. Water Supply (D_{3A}):

Water supply is an essential accessory to maintain a canteen as it is a necessity for the preparation of food, cooking, cleaning and sanitization. Proper availability of fresh water certifies the good quality of food and hygiene. It also ensures the continuation of the operations of the canteen without any retardation.

B. Electricity (D_{3B}):

Unswerving electric supply is an important part to be aware of, as it supplies the energy in cooking appliances, e-payment systems, illuminations, and cold storage equipment. Proper electric supply certifies swift flow of work, convenient storage system along with provides work worthy and well lit surroundings for employees and pupils.

C. Waste Management (D_{3C}):

Waste management is vital in the canteen's site selection as it contributes to maintaining cleanliness, decreases environmental pollution as well as averts problems such as irksome doors or pests. An appropriate disposal system with the adoption of waste refusal gives a welcoming and sterile environment in which to dine.

D. Internet Connectivity (D_{3D}):

It enables rapid technological solutions through the internet and is also helpful in providing streamlined functioning and efficiency improvement. Online order and payment systems, display of digital bills and menu, point of sale systems and different other operational features can be satisfied through the usage of technical advances.

5.4 Safety and Compliance (D_4)

There should be proper safety in the canteen. This consists of flame-proofed surroundings, high hygienic standards and overall security. The canteen should be full of security procedures to shield purchasers and staff.

A. Fire Safety (D_{4A}):

Flame-proofed surroundings are crucial to provide protection both to the pupils and the workers in case of a fire emergency. Approachability to fire safety services and strict fire safety principles, including fire alarms and extinguishers, reduce risks and zero compromise with safety levels insures regular canteen operations. It contributes to overall safety and security for everyone.

B. Hygiene Standards nearby (D_{4B}):

High hygienic standards are essential for choosing the site of the canteen as the quality of food determines the health benefits gained by the students as well as elevating the goodwill of canteen facilities. Placement in clean and neat areas, the positions higher hygienic services are maintained that has to attract more students. It prevents potential health risks and delivers proper sanitation for the preparation and consumption of food materials.

C. Security (D_{4C}):

Safety and security are one of the major things to be taken into consideration for the placement of food services. Both the patrons and the faculties need to be safe along with the apparatus and raw materials. Thefts and vandalism can be deduced by choosing a location with several surveillance cameras, lighting facilities and limited access.

5.5 Environmental Factors (D_5)

There should be consideration of various natural factors considering the surrounding environment. The site of the canteen must avoid places which are flood prone, noisy environment and unpleasant and unsafe to sit and eat over there.

A. Water quality (D_{5A}):

The quality of water that is being supplied in that area is beneficial while selecting the canteen's position. Water is mandatory for the composition and consumption of food and along with that, it is needed for cleaning, washing and drinking purposes. Unsterile water may cause different health issues that will bring down the quality standards of the canteen. In order to build a satisfying environment for the pupil’s quality of water needs to be maintained.

B. Noise Pollution (D_{5B}):

Noise pollution is a beneficial factor that needs to be looked after at the time of choosing a place for food court. Position with retarded noise factors ensures a refreshing and enjoyable eating experience. Students will be able to devour with limited disruption. Socialising become much more delightful. Along with that, the employees also need peaceful surroundings to work in, which is to be provided through this. Altogether less noise pollution delivers a nice environment to the ones giving the service as well as the ones taking the services.

6. Alternative selection and Model structured

This section describes the alternative selection process and model structured procedure in detail. First, the alternative selection process, i.e., the proposed locations for the canteen on the university campus and brief details on the sites. Further, describe the model structure procedure of this study.

6.1 Alternative selection

This section discussed the process of the alternative selection process and verified the description of proposed locations as alternatives. Locations for the canteen in the university campuses were selected based on the requirements of the students and staff by detailed analysis and seeing the university building structured. Further, the proposed locations are verified by the decision experts. The locations for the canteen are geometrically presented in Figure 5.

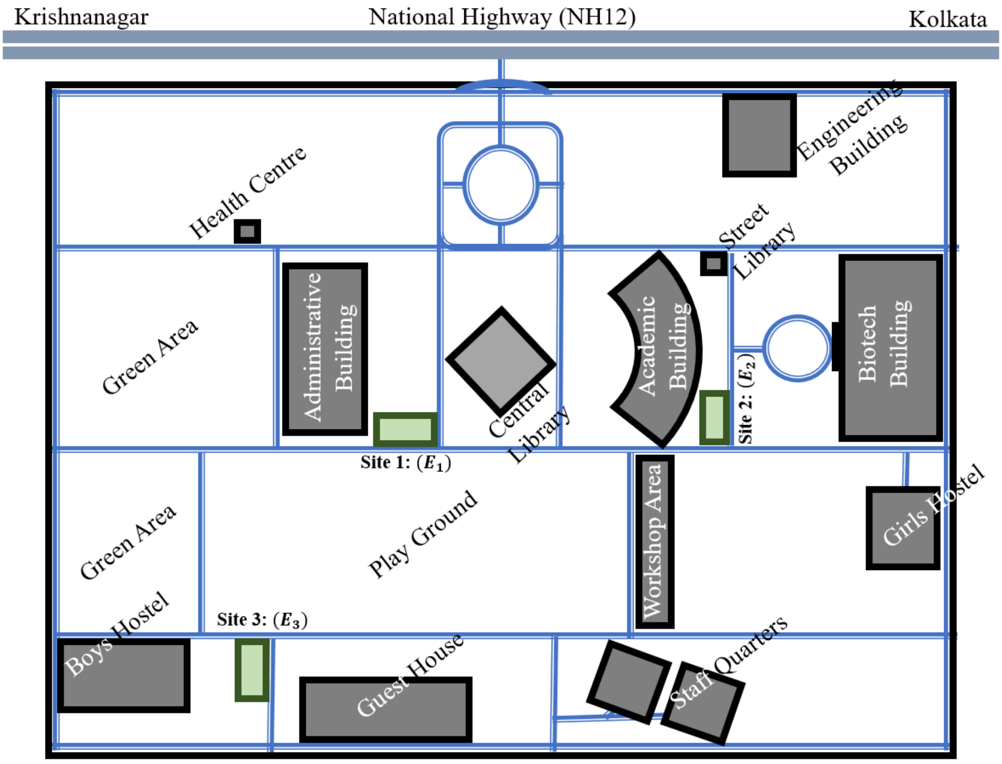

Figure 5. Geometric locations of proposed Canteen sites in the University campus

Three locations are considered for this study as alternatives and the details of the locations are as follows:

I. Spot 1: Near Administrative Building (E_1): The administrative building's closeness to the university canteen gives convenient access mainly for staff and also students to meals and also getting extra refreshments during the working breaks. It enhances informal encounters between staff and students of the university, boosting communication. This site makes the canteen more accessible easily to all on campus. Furthermore, it helps institution visitors easily navigate to find food options easily. Finally, this proximity can save time for staff who actually need coffee, tea or quick meals during their busy schedule.

II. Spot 2: Close to Academic Building (E_2): Faculty and students may easily get snacks and meals in between classes as the university canteen is close to the academic building. It enhances focus on academics during busy schedule. This also provides a social and calm environment where students can discuss various academic topics outside of class. Additionally, it makes easier for faculties and staff to have casual meetings or discussions over meals, which helps them bond better. After considering all things, it can be concluded that it improves campus life by integrating dining options into the academic experience.

III. Spot 3: In proximity to the playground (E_3): Students during sports can readily obtain drinks and food because of the university canteen's proximity to the playground, which helps to recover students' health. During different sports events, this location provides a convenient spot for spectators and participants to gather and refreshments. It also gives as a proper meeting point for students before or after using the playground equipment. This site also fosters an energetic atmosphere and merges social and recreational activities. And finally, it enhances the overall meal selections more enjoyable with sports and leisure activities.

6.2 Model structured

The model formulation of this study is formulated in this section. The five criteria and fourteen sub-criteria are considered for this study, which are described in Section 5 and three alternatives are selected in the university campus, which is covered in Section 6.1, respectively. The ambiguity capturing mathematical tool, the Triangular Neutrosophic Numbers (TNNs), is discussed in Section 3 and the MCDM based optimization techniques are theoretically presented in Section 4. Further, the decision matrices are formulated with 3×5 order and $3 \times (2 + 3 + 4 + 3 + 2) = 3 \times 14$ order for the criteria and sub-criteria, respectively. The structural flowchart of the proposed model is presented in Figure 6. All the data are collected by two decision makers (DMs) or decision experts who are experienced, well knowledged and unbiased in their opinions. The DMs are

(DM 1) A professor from the Civil engineering department with 10 years of experience

(DM 2) A university nominated government officer with 15 years of experience

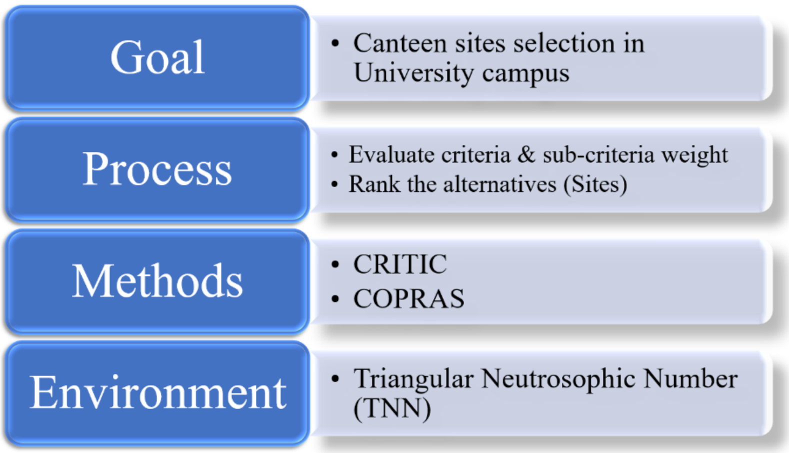

Figure 6. Hierarchical structure of the proposed model

7. Data collection

In this section, we mainly focus on the wise decisions of two decision makers (DMs). They give their right decision of the site selection for canteen in a university campus. We convert this term into a mathematical term with a Triangular Neutrosophic Number (TNN) that is shown in Table 6. The linguistic term of Table 7 is used for the decision matrix, i.e., Criteria vs Alternative and Table 8, Table 9, Table 10, Table 11 and Table 12 represent the decision matrix between criteria vs sub-criteria of the criteria Location (D_1), Space and Layout (D_2), Infrastructure and Utilities (D_3), Safety and Compliance (D_4) and Environmental Factors (D_5), respectively.

Table 6. Comparison table between linguistic terms and the set of considered numbers of TNN

Linguistic Terms	Triangular neutrosophic number (TNN)	De-neutrosophic Value
Absolutely Crucial (AC)	$\{13,15,17; 0.60,0.15,0.20\}$	15.0
Strongly Crucial (SC)	$\{11,13,15; 0.60,0.15,0.20\}$	13.0
Very Crucial (VC)	$\{9,11,13; 0.60,0.15,0.20\}$	11.0
Equally Crucial (EC)	$\{7,9,11; 0.60,0.15,0.20\}$	9.0
Weakly Crucial (WC)	$\{5,7,9; 0.60,0.15,0.20\}$	7.0
Low Crucial (LC)	$\{3,5,7; 0.60,0.15,0.20\}$	5.0
Poorly Crucial (PC)	$\{\{1,3,5; 0.60,0.15,0.20\}$	3.0

Table 7. Decision matrix in linguistic terms of criteria and alternatives given by two DMs

	Criteria vs Alternatives	Location (D_1)	Space and Layout (D_2)	Infrastructure and Utilities (D_3)	Safety and Compliance (D_4)	Environmental Factors (D_5)
DM1	Spot 1: Near Administrative Building (E_1)	SC	VC	EC	SC	VC
	Spot 2: Close to Academic Building (E_2)	AC	AC	SC	SC	VC
	Spot 3: In proximity to the playground (E_3)	EC	EC	WC	LC	EC
	Criteria vs Alternatives	Location (D_1)	Space and Layout (D_2)	Infrastructure and Utilities (D_3)	Safety and Compliance (D_4)	Environmental Factors (D_5)
DM2	Spot 1: Near Administrative Building(E_1)	VC	VC	SC	SC	EC
	Spot 2: Close to Academic Building (E_2)	AC	SC	SC	AC	VC
	Spot 3: In proximity to the playground (E_3)	EC	VC	WC	LC	PC

Table 8. Decision matrix between sub-criteria of Location (D_1) and alternatives by DMs

	Sub-Criteria vs Alternatives	Proximity to Students (D_{1A})	Accessibility (D_{1B})
DM1	Spot 1: Near Administrative Building (E_1)	VC	AC
	Spot 2: Close to Academic Building (E_2)	AC	SC
	Spot 3: In proximity to the playground (E_3)	VC	EC
	Sub-Criteria vs Alternatives	Proximity to Students (D_{1A})	Accessibility (D_{1B})
DM2	Spot 1: Near Administrative Building (E_1)	SC	SC
	Spot 2: Close to Academic Building (E_2)	AC	AC
	Spot 3: In proximity to the playground (E_3)	SC	VC

Table 9. Decision matrix between sub-criteria of Space and Layout (D_2) and alternatives by DMs

	Sub-Criteria vs Alternatives	Size (D_{2A})	Ventilation and Lighting (D_{2B})	Restroom Facilities (D_{2C})
DM1	Spot 1: Near Administrative Building (E_1)	AC	VC	AC
	Spot 2: Close to Academic Building (E_2)	SC	AC	AC
	Spot 3: In proximity to the playground (E_3)	VC	SC	VC
	Sub-Criteria vs Alternatives	Size (D_{2A})	Ventilation and Lighting (D_{2B})	Restroom Facilities (D_{2C})
DM2	Spot 1: Near Administrative Building (E_1)	AC	SC	SC
	Spot 2: Close to Academic Building (E_2)	SC	VC	AC
	Spot 3: In proximity to the playground (E_3)	SC	VC	EC

Table 10. Decision matrix between sub-criteria of Infrastructure and Utilities (D_3) and alternatives by DMs

	Sub-Criteria vs Alternatives	Water Supply (D_{3A})	Electricity (D_{3B})	Waste Management (D_{3C})	Internet Connectivity (D_{3D})
DM1	Spot 1: Near Administrative Building (E_1)	EC	AC	SC	AC
	Spot 2: Close to Academic Building (E_2)	VC	SC	VC	SC
	Spot 3: In proximity to the playground (E_3)	WC	EC	LC	VC
	Sub-Criteria vs Alternatives	Water Supply (D_{3A})	Electricity (D_{3B})	Waste Management (D_{3C})	Internet Connectivity (D_{3D})
DM2	Spot 1: Near Administrative Building (E_1)	WC	SC	VC	AC
	Spot 2: Close to Academic Building (E_2)	SC	AC	EC	AC
	Spot 3: In proximity to the playground (E_3)	LC	EC	PC	EC

Table 11. Decision matrix between sub-criteria of Safety and Compliance (D_4) and alternatives by DMs

	Sub-Criteria vs Alternatives	Fire Safety (D_{4A})	Hygiene Standards nearby (D_{4B})	Security (D_{4C})
DM1	Spot 1: Near Administrative Building (E_1)	SC	SC	VC
	Spot 2: Close to Academic Building (E_2)	AC	VC	AC
	Spot 3: In proximity to the playground (E_3)	EC	LC	PC
	Sub-Criteria vs Alternatives	Fire Safety (D_{4A})	Hygiene Standards nearby (D_{4B})	Security (D_{4C})
DM2	Spot 1: Near Administrative Building (E_1)	AC	VC	VC
	Spot 2: Close to Academic Building (E_2)	AC	EC	SC
	Spot 3: In proximity to the playground (E_3)	WC	PC	LC

Table 12. Decision matrix between sub-criteria of Environmental Factors (D_5) and alternatives by DMs

	Sub-Criteria vs Alternatives	Water quality (D_{5A})	Noise Pollution (D_{5B})
DM1	Spot 1: Near Administrative Building (E_1)	VC	AC
	Spot 2: Close to Academic Building (E_2)	SC	EC
	Spot 3: In proximity to the playground (E_3)	WC	LC
	Sub-Criteria vs Alternatives	Water quality (D_{5A})	Noise Pollution (D_{5B})
DM2	Spot 1: Near Administrative Building (E_1)	VC	SC
	Spot 2: Close to Academic Building (E_2)	VC	EC
	Spot 3: In proximity to the playground (E_3)	EC	PC

8. Numerical Illustration and Discussion

In this section, we explain the required numerical results of the canteen site selection problem by MCDM based methodology and how it varies with three different sites numerically. This decision-making method is used to find criteria weights of the criteria and sub-criteria. It also calculates the rank of alternatives. CRITIC and COPRAS methods are used to evaluate this weight and rank, respectively.

At first, we computed the weight of the criteria in Table 13 and the local and the global weight of the sub-criteria in Table 14 with CRITIC methodology, discussed in Section 4.1. The data sets from Section 7 are used to solve this site selection problem.

Table 13. Criteria weight evaluated by CRITIC method

Factor of the Canteen Site Selection in a University Campus	Weight
Location (D_1)	0.1252
Space and Layout (D_2)	0.3571
Infrastructure and Utilities (D_3)	0.1007
Safety and Compliance (D_4)	0.2138
Environmental Factors (D_5)	0.1732

Remark 2. We notice that Space and Layout (D_2) criteria are the most weighted and Infrastructure and Utilities (D_3) are the less weighted criteria in Table 13 and Figure 7. Safety and Compliance (D_4), Environmental Factors (D_5) and Location (D_1) get the second, third and fourth weighted criteria, respectively.

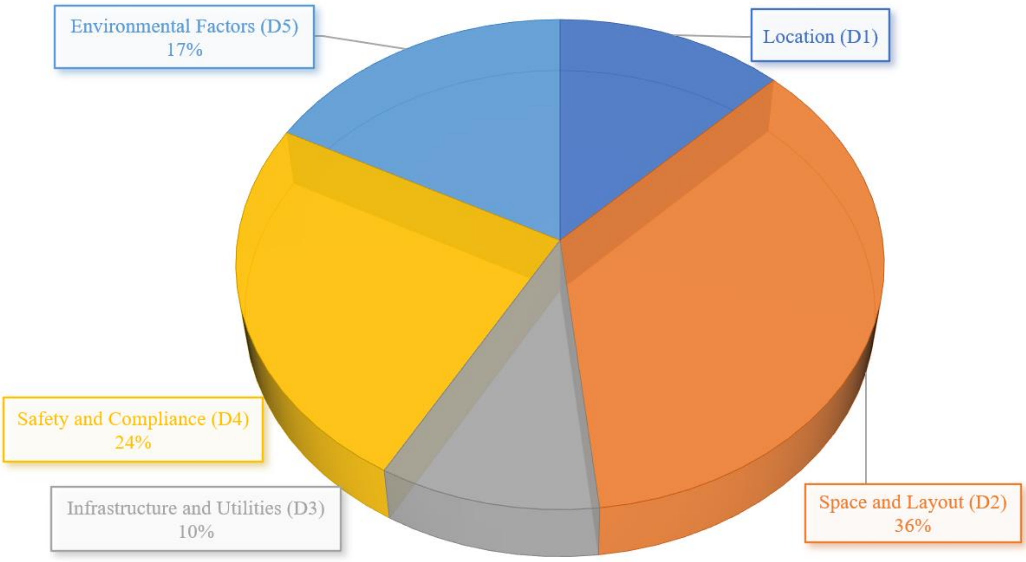

Figure 7. Criteria weight evaluated by CRITIC weighted technique

Table 14. Weight of the sub-criteria determined by CRITIC procedure

Sub-criteria	Local Weight	Global Weight
	Location (D_1)	
Proximity to Students (D_{1A})	0. 5	0.0626
Accessibility (D_{1B})	0.5	0.0626
	Space and Layout (D_2)	
Size (D_{2A})	0.386207	0.1379
Ventilation and Lighting (D_{2B})	0.428221	0.1529
Restroom Facilities (D_{2C})	0.185572	0.0663
	Infrastructure and Utilities (D_3)	
Water Supply (D_{3A})	0.42618	0.0429
Electricity (D_{3B})	0.14129	0.0142
Waste Management (D_{3C})	0.23721	0.0239
Internet Connectivity (D_{3D})	0.19531	0.0197
	Safety and Compliance (D_4)	
Fire Safety (D_{4A})	0.172319	0.0420
Hygiene Standards nearby (D_{4B})	0.496994	0.1212
Security (D_{4C})	0.330687	0.0806
	Environmental Factors (D_5)	
Water quality (D_{5A})	0.5	0.0866
Noise Pollution (D_{5B})	0.5	0.0866

Remark 3. Table 14 represents the sub-criteria weight based on the local and global. Proximity to Students (D_{1A}) and Accessibility (D_{1B}) be the same weighted sub-criteria of Location (D_1). And, the same thing happened with Criterion five, i.e., Environmental Factors (D_5). Ventilation and Lighting (D_{2B}), Water Supply (D_{3A}), Hygiene Standards nearby (D_{4B}) are the highest sub-criteria among the sub-criteria of the criteria Space and Layout (D_2), Infrastructure and Utilities (D_3), Safety and Compliance (D_4), respectively. The Pi diagram of the global weight of sub-criteria is presented in Figure 8 graphically.

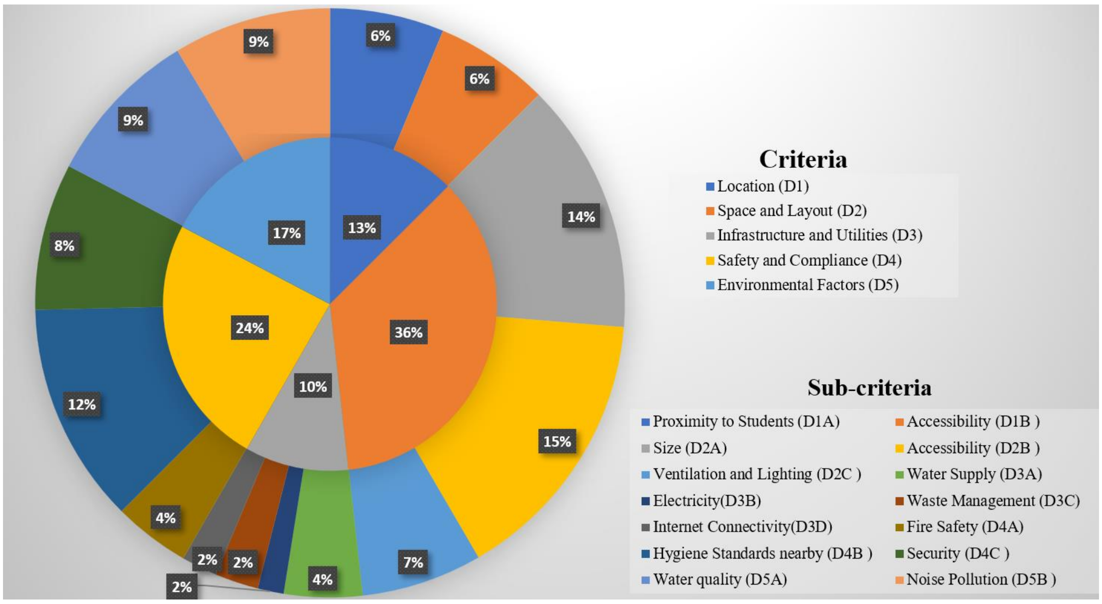

Figure 8. Pi diagram of the criteria and sub-criteria weight

Three distinct locations are selected as choices in order to verify and consider the best site for a canteen in a university campus. We use the COPRAS method of MCDM methodology described in Section 4.2. We present the rank of the selected alternatives in Table 15 with the COPRAS technology to realise the difference between the best and worst site for the canteen based on the weighting of different criteria and sub-criteria in Table 13 and Table 14, respectively.

Table 15. Ranking of the alternatives and their associated values by COPRAS method

Alternative	S_m^+	S_m^-	H_m	K_m	Ranking
Spot 1: Near Administrative Building (E_1)	15.3869	1.9321	16.3508	92.9166	2
Spot 2: Close to Academic Building (E_2)	16.4642	1.6437	17.5973	100	1
Spot 3: In proximity to the playground (E_3)	9.9186	0.8128	12.2101	69.3859	3
$S_{min} = \min\{S_m^- : m = 1,2,\ldots,\delta\} = 0.8128$					

Remark 4. According to the two DMs' decision, it is easy to say that Spot 2: Close to Academic Building (E_2) is the most ideal and Spot 3: In proximity to the playground (E_3) is less ideal site for this site selection problem. And, Spot 1: Near Administrative Building (E_1) be the medium place for structuring it. Figure 9 shows the ranking of the sites as alternatives using a Bar diagram.

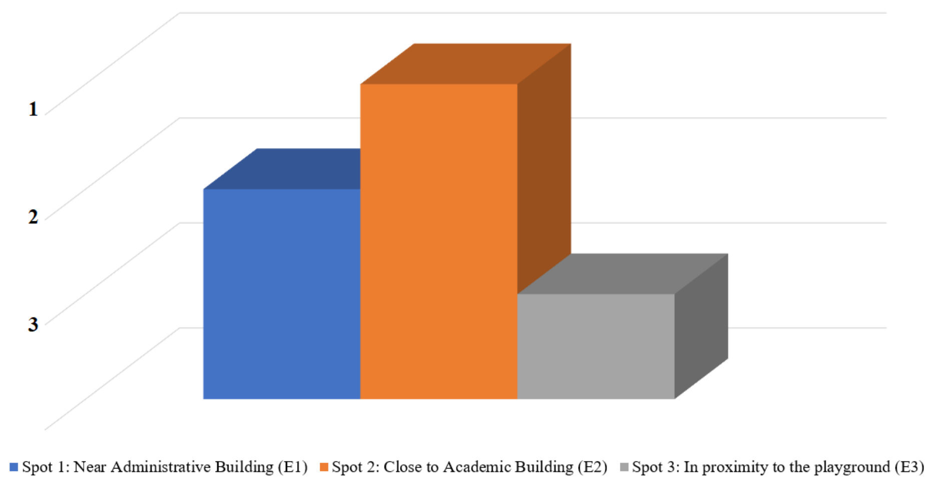

Figure 9. Ranking of the different proposed canteen sites using the COPRAS process

9. Sensitivity analysis

The sensitivity analysis of this research is presented in this section. There are four cases considered in this study. Further, the rankings of the alternatives are comparatively analysed by the main results. The following cases are described as follows:

9.1 Case 1: Remove criteria Safety and Compliance (D_4):

In this case, to evaluate the sensitivity analysis of this site selection problem for the university canteen, we remove the criteria and sub-criteria of Safety and Compliance (D_4). Since the university provides safety everywhere, the problem is analyzed here without these criteria. Then, based on the two DMs decisions and considering the rest of the criteria, we notice that Spot 2: Close to Academic Building (E_2) is the ideal place for this problem and the ranking result is the same as our main structured model.

Remark 5. E_2, E_1 and E_3 get the Rank 1, 2 and 3, respectively, which is expressed in Table 16. Figure 10 explains this case in a clear way.

9.2 Case 2: Remove criteria Environmental Factors (D_5):

We express this case except the criteria and its sub-criteria of D_5, i.e., environmental factors. So, from the perspectives of the two DMs, we can analyze the remaining categories. Now, Spot 2: Close to Academic Building (E_2) is the perfect and Spot 3: In proximity to the playground (E_3) is the less perfect place for this site selection problem.

Remark 6. E_2, E_1 and E_3 hold the Rank 1, 2 and 3, particularly in Table 16. Figure 10 also presents it easily.

9.3 Case 3: Interchange the weights of the criteria and sub-criteria of Space and Layout (D_2) and Safety and Compliance (D_4):

We note that Space and Layout (D_2) and Safety and Compliance (D_4) are almost equally important factors in this problem. So, we interchange the weights of their criteria and sub-criteria. After that, we proceeded to the problem and found that Spot 2 is the best location for the canteen.

Remark 7. E_2, E_1 and E_3 occupy Rank 1,2 and 3 individually in this case in Table 16 and Figure 10 expresses it graphically.

9.4. Case 4: Increase the weight of the criteria Infrastructure and Utilities (D_3) and associated sub-criteria:

In some cases, we note that the factor Infrastructure and Utilities (D_3) plays an important role in the canteen site selection problem. Here, we increase the weight of this criteria and its' associated sub-criteria. And finally, we get that Spot 2: Close to Academic Building (E_2) is the ideal place for a canteen in the university.

Remark 8. We see that E_2 holds Rank 1 and E_3 holds Rank 3, which is the same as the main model and it is shown in Table 16. Then, Figure 10 explains this case easily.

Table 16. Ranking of the alternatives by various sensitivity analysis cases

Alternative	Case 1	Case 2	Case 3	Case 4	Main Model
Spot 1: Near Administrative Building (E_1)	2	2	2	2	2
Spot 2: Close to Academic Building (E_2)	1	1	1	1	1
Spot 3: In proximity to the playground (E_3)	3	3	3	3	3

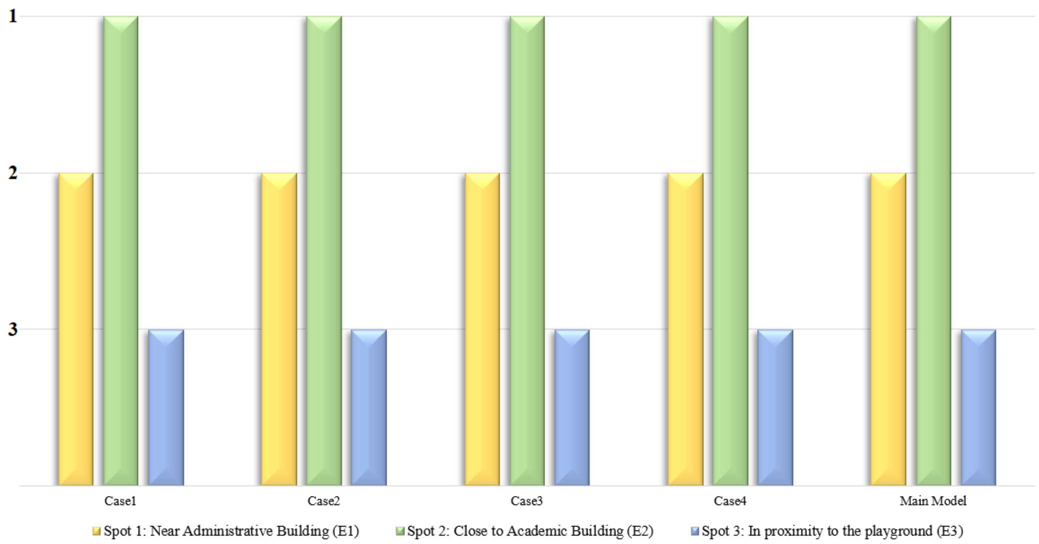

Figure 10. Sensitivity analysis in four several cases

10. Research implication

The location selection for a canteen on a university campus has important research implications in a number of areas, i.e.,

(i) User/ Member Accessibility: Studying the location can reveal how staff and students can easily access the university canteen, which impacts usage and satisfaction.
(ii) Traffic Analysis: This study can focus on the students, staff and others to flow patterns and identify the optimal places which attract higher foot traffic and making sure that the canteen is frequently visited.
(iii) Health with Safety: Research could assess how site selection affects standards of hygiene and safety protocols.
(iv) Environmental Effect: Investigating the site's closeness to garbage elimination, utilities, and natural resources reduces the impact on the environment and optimizes energy use.
(v) Social and Cultural Factors: The canteen site selection problem may impact students and stuffs interactions, serving as a social hub that encourages community engagement.
(vi) Infrastructure Encouragement: Construction and maintenance prices may be decreased by selecting a location with planned or current assistance for energy, garbage management and water services.
(vii) Financial Viability: Research can analyse how proximity to the main university areas, i.e., libraries, classrooms, etc., affects revenue, operational expenses and overtime sustainability.
(viii) Noise or Disturbance: By reducing noise or disturbance to nearby study spaces, research can compute the impact of location on the academic surroundings.
(ix) Prospective Growth: Research on location scalability is essential to ensure the canteen can accommodate expanding student numbers or raised demand over time.

11. Conclusions and Future Research Scope

Selecting the right spot for a university canteen is very significant for enhancing the student and stuff contentment and campus life. It is more convenient for staff and students to have meals during breaks or in between classes when a perfect site is provided. A proper location selection can also reduce chaos and ensure efficient service during busy hours. It also encourages social contact and establishes a common area where students can relax and work together. Staff can also catch up on unofficial conversations between themselves at this place. Additionally, locating the canteen near other key facilities like academic buildings, administrative buildings or playgrounds can promote waking and ease of use. Careful site selection can also encourage sustainable behaviour such as reducing the need for long-distance travel across campus. A well-placed canteen not only serves as a place for the meals but becomes an energetic area of campus life and it also contributes to the overall well-being and sense of belonging to the community. In the end, the canteen's site selection plays the main role in the university campus experience.

This research work has some limitations or constraints which help to extend this work in future research. The probable future research scope are discussed as follows,

a) We select five several criteria and the first, second, third, fourth and fifth criteria have two, three, four, three, two different sub-criteria, respectively. We may consider many other criteria and sub-criteria for this site selection decision making model formulation in future.
b) More locations on the university campus as alternatives will be taken for future analysis. We may extend our data set to ensure that the results are accurate.
c) In order to establish the criteria weight and rank the alternatives, many other MCDM techniques can be used.
d) Different fuzzy numbers, such as triangular, trapezoidal, pentagonal, hexagonal, heptagonal, intuitionistic; probabilistic linguistic word sets, etc., may be taken into consideration in order to reflect the ambiguity of the data collection. Moreover, various de-neutrosophic methods can also be considered for de-fuzzifying the considered fuzzy numbers.

e) For the proposed model's sensitivity analysis, more cases may be taken in future research.

References

Adhikari, D., Gazi, K. H., Sobczak, A., Giri, B. C., Salahshour, S., & Mondal, S. P. (2024). Ranking of Different States in India Based on Sustainable Women Empowerment using MCDM Methodology under Uncertain Environment. Journal of Uncertain Systems, 17(4), 2450010.

Ahmadsaraei, M. S., Koshksaray, A. A., Soleimani, M., & Kazemi, Z. (2022). Sustainable Supply Chain Risk in Food Packaging Industry: Integrated Delphi-CRITIC-COPRAS Method Using Fuzzy Set Theory. International Journal of Business, 2(1), 61-78.

Akram, M., Ramzan, N., & Feng, F. (2022). Extending COPRAS method with linguistic Fermatean fuzzy sets and Hamy mean operators. Journal of Mathematics, 2022(1), 8239263.

Alamin, A., Rahaman, M., & Mondal, S. P. (2025). Geometric Approach for Solving First Order Non-Homogenous Fuzzy Difference Equation. Spectrum of Operational Research, 2(1), 61-71.

Arora, H. D., & Naithani, A. (2023). Some distance measures for triangular fuzzy numbers under technique for order of preference by similarity to ideal solution environment. Opsearch, 60(2), 701-719.

Bhowmik, M., & Pal, M. (2009). Intuitionistic neutrosophic set. Journal of Information and Computing Science, 4(2), 142-152.

Biswas, A., Gazi, K. H., Bhaduri, P., & Mondal, S. P. (2025a). Site Selection for Girls Hostel in a University Campus by MCDM based Strategy. Spectrum of Decision Making and Applications, 2(1), 68-93.

Biswas, A., Gazi, K. H., Sankar, P. M., & Ghosh, A. (2025b). A decision-making framework for sustainable highway restaurant site selection: AHP-TOPSIS approach based on the fuzzy numbers. Spectrum of operational research, 2(1), 1-26.

Boz, E., Çalık, A., & Çizmecioğlu, S. (2024). Selecting an Air Carrier for the Transport of Hazardous Goods: A Type-2 Neutroscopic COPRAS Approach. In C. Kahraman, S. Cevik Onar, S. Cebi, B. Oztaysi, A. C. Tolga, & I. Ucal Sari, (Eds.), Intelligent and Fuzzy Systems (INFUS 2024), Lecture Notes in Networks and Systems, vol 1090 (pp. 589-596). Cham: Springer.

Božanić, D., Pamučar, D., & Komazec, N. (2023). Applying D numbers in risk assessment process: General approach. Journal of Decision Analytics and Intelligent Computing, 3(1), 286–295.

Brauers, W. K. M., & Zavadskas, E. K. (2010). Project management by MULTIMOORA as an instrument for transition economies. Technological and economic development of economy, 16(1), 5-24.

Chakraborty, A. (2020). A new score function of pentagonal neutrosophic number and its application in networking problem. International Journal of Neutrosophic Science, 1(1), 40-51.

Das, S., Roy, B. K., Kar, M. B., Kar, S., & Pamučar, D. (2020). Neutrosophic fuzzy set and its application in decision making. Journal of Ambient Intelligence and Humanized Computing, 11, 5017-5029.

Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The critic method. Computers & Operations Research, 22(7), 763-770.

Edalatpanah, S. A. (2020). A direct model for triangular neutrosophic linear programming. International journal of neutrosophic science, 1(1), 19-28.

Fu, M., & Wang, D. (2020). Evaluation of Unit Canteen Suppliers Based on Entropy Method and Analytic Hierarchy Process. In E3S Web of Conferences, vol 218 (p. 03054). EDP Sciences.

Gani, A. N., & Assarudeen, S. M. (2012). A new operation on triangular fuzzy number for solving fuzzy linear programming problem. Applied Mathematical Sciences, 6(11), 525-532.

Gazi, K. H., Biswas, A., Singh, P., Rahaman, M., Maity, S., Mahata, A., & Mondal, S. P. (2024). A Comprehensive Literature Review of Fuzzy Differential Equations with Applications. Journal of Fuzzy Extension and Applications. Articles in Press. https://doi.org/10.22105/jfea.2024.449970.1426.

Gazi, K. H., Raisa, N., Biswas, A., Azizzadeh, F., & Mondal, S. P. (2025). Finding the Most Important Criteria in Women's Empowerment for Sports Sector by Pentagonal Fuzzy DEMATEL Methodology. Spectrum of Decision Making and Applications, 2(1), 28-52.

Hamza, A., Farooq, S., & Rafaqat, M. (2021). Triangular Neutrosophic Topology. Neutrosophic Sets and Systems, 39, 31-43.

Hezam, I. M., Mishra, A. R., Rani, P., Saha, A., Smarandache, F., & Pamucar, D. (2023). An integrated decision support framework using single-valued neutrosophic-MASWIP-COPRAS for sustainability assessment of bioenergy production technologies. Expert Systems with Applications, 211, 118674.

Hussain, A., & Ullah, K. (2024). An Intelligent Decision Support System for Spherical Fuzzy Sugeno-Weber Aggregation Operators and Real-Life Applications. Spectrum of Mechanical Engineering and Operational Research, 1(1), 177-188.

Jannah, R., & Rahayu, R. (2023). Analysis of Canteen Selection for Bunga Bangsa Cirebon Students Using the Weighted Product (WP) Method. International Journal of Social Service and Research, 3(12), 3298-3305.

Kadam, S., Kondhalkar, V., Purswani, K., Dandegaonkar, Y., & Sabnis, M. (2024). Canteen Automation System. International Journal of Creative Research Thoughts (IJCRT), 12(3), 428-434.

Kamali Saraji, M., Streimikiene, D., & Kyriakopoulos, G. L. (2021). Fermatean fuzzy CRITIC-COPRAS method for evaluating the challenges to industry 4.0 adoption for a sustainable digital transformation. Sustainability, 13(17), 9577.

Kumar, R., Khepar, J., Yadav, K., Kareri, E., Alotaibi, S. D., Viriyasitavat, W., Gulati, K., Kotecha, K., & Dhiman, G. (2022). A systematic review on generalized fuzzy numbers and its applications: past, present and future. Archives of Computational Methods in Engineering, 29(7), 5213-5236.

Li, L. (2019). Spatial pattern and fine design of community elders' canteen based on aging vision. In Proceedings of the International Academic Conference on Frontiers in Social Sciences and Management Innovation (IAFSM 2018), (pp. 326-331). Atlantis Press.

Madić, M., Petrović, G., Petković, D., & Janković, P. (2024). Traditional and Integrated MCDM Approaches for Assessment and Ranking of Laser Cutting Conditions. Spectrum of Mechanical Engineering and Operational Research, 1(1), 250-257.

Mishra, A. R., Liu, P., & Rani, P. (2022). COPRAS method based on interval-valued hesitant Fermatean fuzzy sets and its application in selecting desalination technology. Applied soft computing, 119, 108570.

Mishra, A. R., Pamucar, D., Rani, P., Shrivastava, R., & Hezam, I. M. (2024). Assessing the sustainable energy storage technologies using single-valued neutrosophic decision-making framework with divergence measure. Expert Systems With Applications, 238, 121791.

Mohamad, M., Alfat, L., & Madzli, N. F. D. (2021). Mobile school canteen food ordering system. Mathematical Sciences and Informatics Journal, 2(2), 102-110.

Mohamed, M., Abdel-Baset, M., Smarandache, F., & Zhou, Y. (2017). A critical path problem using triangular neutrosophic number. 2017 IEEE International Conference on INnovations in Intelligent SysTems and Applications (INISTA), (pp. 403-407). Gdynia: Gdynia Maritime University.

Momena, A. F., Gazi, K. H., Rahaman, M., Sobczak, A., Salahshour, S., Mondal, S. P., & Ghosh, A. (2024). Ranking and challenges of supply chain companies using mcdm methodology. Logistics, 8(3), 87.

Mondal, S. P., & Roy, T. K. (2015). System of differential equation with initial value as triangular intuitionistic fuzzy number and its application. International Journal of Applied and Computational Mathematics, 1, 449-474.

Mondal, S. P., Goswami, A., & Kumar De, S. (2019). Nonlinear triangular intuitionistic fuzzy number and its application in linear integral equation. Advances in Fuzzy Systems, 2019(1), 4142382.

Muthulakshmi, M., Sindhu,T. G., Tamilarasi, C., & Sathyaswathi, K. (2022). Some Properties of Neutrosophic Real Numbers. International Journal of Creative Research Thoughts, 10(6), 296-302.

Navelkar, G., Chanda, B., Sharma, V., Gracias, A., Jose, B., & Menezes, V. (2022) Canteen Management System. International Research Journal of Engineering and Technology, 9(7), 2619-2622.

Pamucar, D., Deveci, M., Schitea, D., Erişkin, L., Iordache, M., & Iordache, I. (2020). Developing a novel fuzzy neutrosophic numbers based decision making analysis for prioritizing the energy storage technologies. International journal of hydrogen energy, 45(43), 23027-23047.

Pathinathan, T., Ponnivalavan, K., & Dison, E. M. (2015). Different types of fuzzy numbers and certain properties. Journal of computer and mathematical sciences, 6(11), 631-651.

Patil, S. B., Patole, T. A., Jadhav, R. S., Suryawanshi, S. S., & Raykar, S. J. (2022). Complex Proportional Assessment (COPRAS) based Multiple-Criteria Decision Making (MCDM) paradigm for hard turning process parameters. Materials today: Proceedings, 59, 835-840.

Rahim, R., Siahaan, A. P. U., Wijaya, R. F., Hantono, H., Aswan, N., Thamrin, S., Sari, D. A. P., Agustina, S., Santosa, R. B., Muttaqin, W. M., Sujito, S., Yulia, Y., Fatmasari, R., Ikhwan, A., Sugiarto, I., Purnomo, A., Anam, F., Kulsum, N. M., Diawati, P., Mina, R., & Sujarwo, S. (2018). Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for decision support system in top management. International Journal of Engineering & Technology, 7(3-4), 290-293.

Saraji, M. K., Streimikiene, D., & Lauzadyte-Tutliene, A. (2021). A novel pythogorean fuzzy-SWARA-CRITIC-COPRAS method for evaluating the barriers to developing business model innovation for sustainability. In Handbook of research on novel practices and current successes in achieving the sustainable development goals (pp. 1-31). IGI Global.

Schneider, M., Nössler, C., & Lührmann, P. M. (2021). Environmental intervention in a university canteen with focus on decision guidance—effects on sale and daily consumption of vegetables and fruit. International Journal of Environmental Research and Public Health, 18(19), 10443.

Sholihah, V. M., Kusna, A., Mahardika, B. A., Nugraheni, D. R., Eriyani, D., Yulindasari, N. O., Taftania, S., & Nurabadi, A. (2020). Analysis of Canteen Services in Educational Institutions using Force Field Analysis Approach. In Proceedings of 1st International Conference on Information Technology and Education (ICITE 2020) (pp. 520-525). Atlantis Press.

Sing, P., Rahaman, M., & Sankar, S. P. M. (2024c). Solution of fuzzy system of linear equation under different fuzzy difference ideology. Spectrum of operational research, 1(1), 64-74.

Singh, P., Gazi, K. H., Rahaman, M., Basuri, T., & Mondal, S. P. (2024a). Solution strategy and associated result for fuzzy mellin transformation. Franklin Open, 7, 100112.

Singh, P., Gazi, K. H., Rahaman, M., Salahshour, S., & Mondal, S. P. (2024b). A fuzzy fractional power series approximation and Taylor expansion for solving fuzzy fractional differential equation. Decision Analytics Journal, 10, 100402.

Smarandache, F. (2005). Neutrosophic set-a generalization of the intuitionistic fuzzy set. International journal of pure and applied mathematics, 24(3), 287.

Smarandache, F. (2014). Introduction to Neutrosophic Statistics. Craiova & Columbus: Sitech & Educational Publishing.

Tešić, D., & Khalilzadeh, M. (2024). Development of the rough Defining Interrelationships Between Ranked criteria II method and its application in the MCDM model. Journal of Decision Analytics and Intelligent Computing, 4(1), 153–164.

Uzun, B., Almasri, A., & Uzun Ozsahin, D. (2021). Preference ranking organization method for enrichment evaluation (Promethee). In D. Uzun Ozsahin, H. Gökçekuş, B. Uzun, J. LaMoreaux (Eds.), Application of Multi-Criteria Decision Analysis in Environmental and Civil Engineering. Professional Practice in Earth Sciences (pp. 37-41). Cham: Springer.

Vahdani, B., Mousavi, S. M., Tavakkoli-Moghaddam, R., & Hashemi, H. (2013). A new design of the elimination and choice translating reality method for multi-criteria group decision-making in an intuitionistic fuzzy environment. Applied Mathematical Modelling, 37(4), 1781-1799.

Wang, J., Ding, D., Liu, O., & Li, M. (2016). A synthetic method for knowledge management performance evaluation based on triangular fuzzy number and group support systems. Applied Soft Computing, 39, 11-20.

Wei, G., Wu, J., Guo, Y., Wang, J., & Wei, C. (2021). An extended COPRAS model for multiple attribute group decision making based on single-valued neutrosophic 2-tuple linguistic environment. Technological and Economic Development of Economy, 27(2), 353-368.

Wyse, R., Gabrielyan, G., Wolfenden, L., Yoong, S., Swigert, J., Delaney, T., Lecathelinais, C., Ooi, J. Y., Pinfold, J. & Just, D. (2019). Can changing the position of online menu items increase selection of fruit and vegetable snacks? A cluster randomized trial within an online canteen ordering system in Australian primary schools. The American Journal of Clinical Nutrition, 109(5), 1422-1430.

Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8(3), 338-353.

Zavadskas, E. K., Kaklauskas, A., & Šarka, V. (1994). The new method of multicriteria complex proportional assessment of projects. Technological and Economic Development of Economy, 1(3), 131-139.

Zhao, P., Liu, X., Kwan, M. P., & Shi, W. (2020). Unveiling cabdrivers' dining behavior patterns for site selection of 'taxi canteen'using taxi trajectory data. Transportmetrica A: Transport Science, 16(1), 137-160.